



Natural Environment Corrosion Testing at the Kennedy Space Center Beachside Atmospheric Corrosion Test Site

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NASA's Kennedy Space Center
Florida, U.S.A.**

Concepts in Natural Environments Corrosion Testing Workshop

2017 DoD-Allied Nations

Technical Corrosion Conference

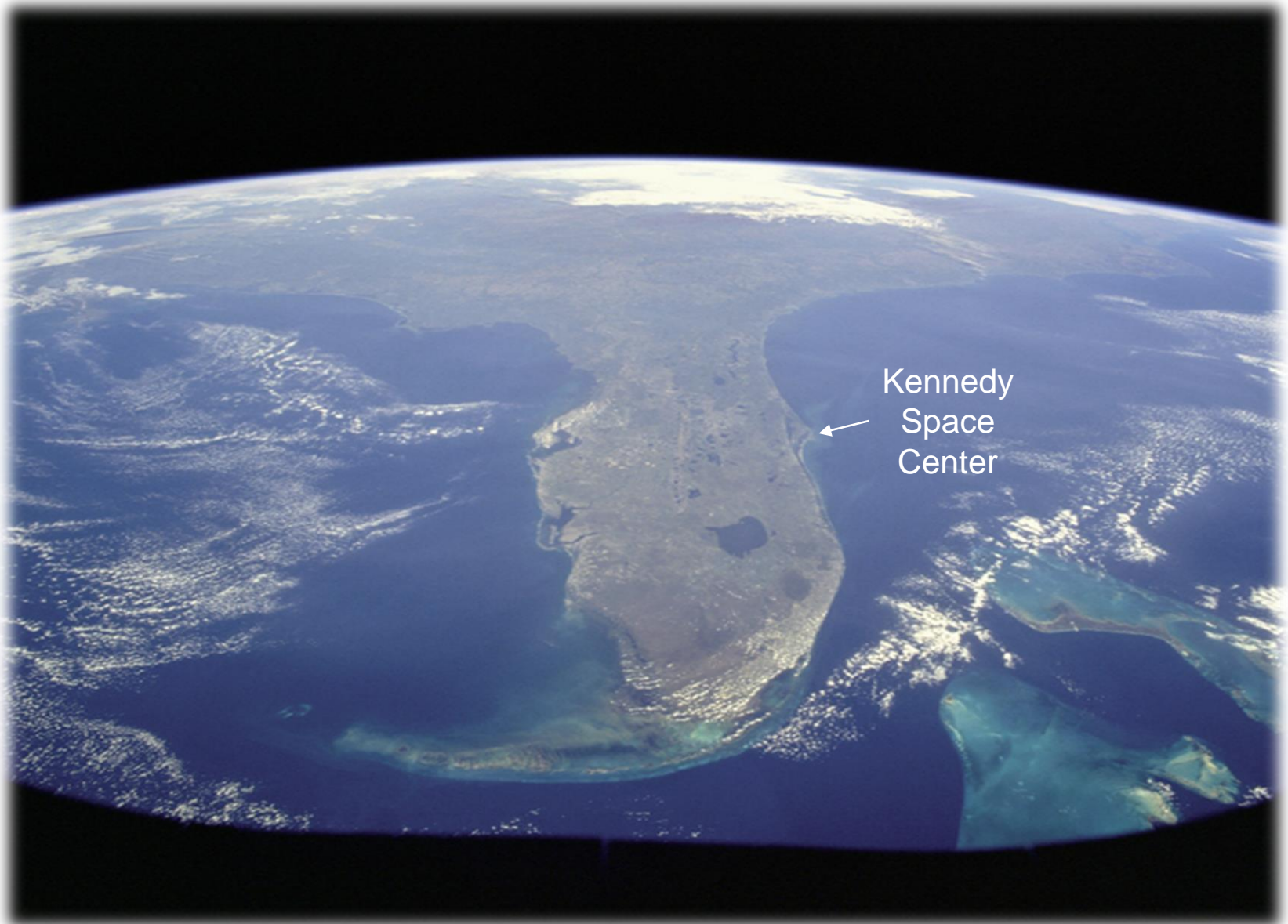
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Objective



- **This presentation will provide an overview of how NASA has been conducting corrosion testing in the Natural Marine Environment at the Kennedy Space Center, Florida, U.S.A**
- **The following questions will be addressed:**
 - ❑ **What factors should be considered when selecting and constructing a test site?**
 - ❑ **What are the attributes of a “good” test site? Is more severe always better?**
 - ❑ **What environmental parameters should be monitored? How frequently?**
 - ❑ **What factors should be considered when designing test specimens?**
 - ❑ **Are current test standards sufficient?**
 - ❑ **How do diurnal, annual and other fluctuations in corrosivity influence tests?**
 - ❑ **How are test results interpreted? Can they be quantified?**

Our Location



Timeline of Corrosion Testing and Technology Development at KSC



1962

1966

1981

1985-
1987

2000

2004

Launch
Operations
start at KSC

Corrosion
failures
begin



Atmospheric
exposure
testing begins
near the
launch pads



Space Shuttle
introduces
acid
deposition
products that
make
corrosion
worse



Accelerated
corrosion testing
(salt fog and
electrochemical)
begins



Corrosion
Technology
Laboratory is
created

The Corrosion
Technology
Laboratory starts
developing new
corrosion
protection
technologies and
test methods

Corrosion Technology Laboratory

Site Map



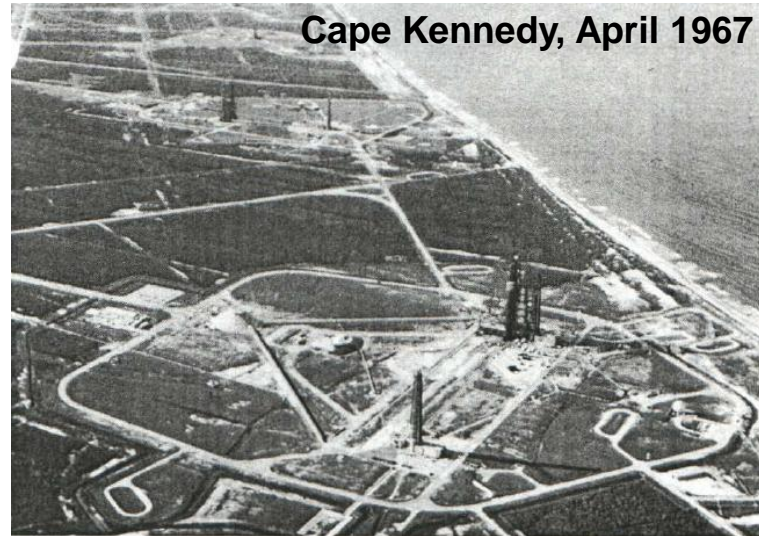
Corrosion testing and failure analysis

Corrosion testing and
technical innovation

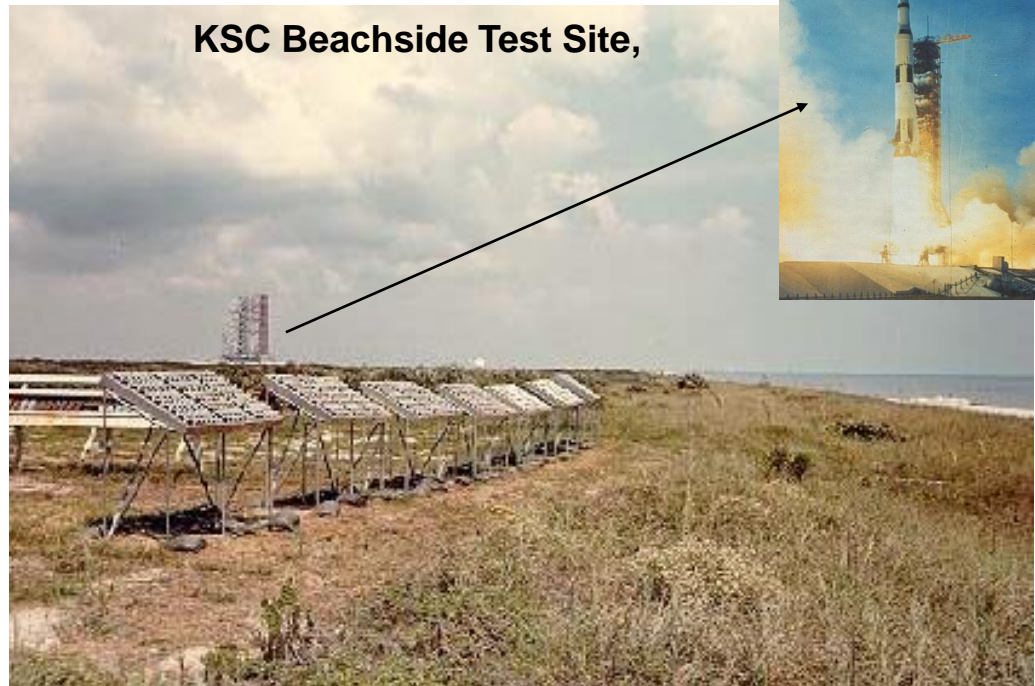
Beachside Atmospheric Exposure Test Site Establishment



- **1962:** The Kennedy Space Center (KSC) begins operating as NASA's launch center for both manned and unmanned missions. The naturally corrosive marine environment causes many corrosion failures.
- **1966:** First atmospheric exposure testing of coatings for corrosion protection of carbon steel begins near the Cape Kennedy launch pads during the Gemini/Apollo Programs.
- **1969:** The NASA Beachside Corrosion Test Site established more controlled and cost effective ways to conduct testing on coatings for carbon steel in a seacoast launch environment.



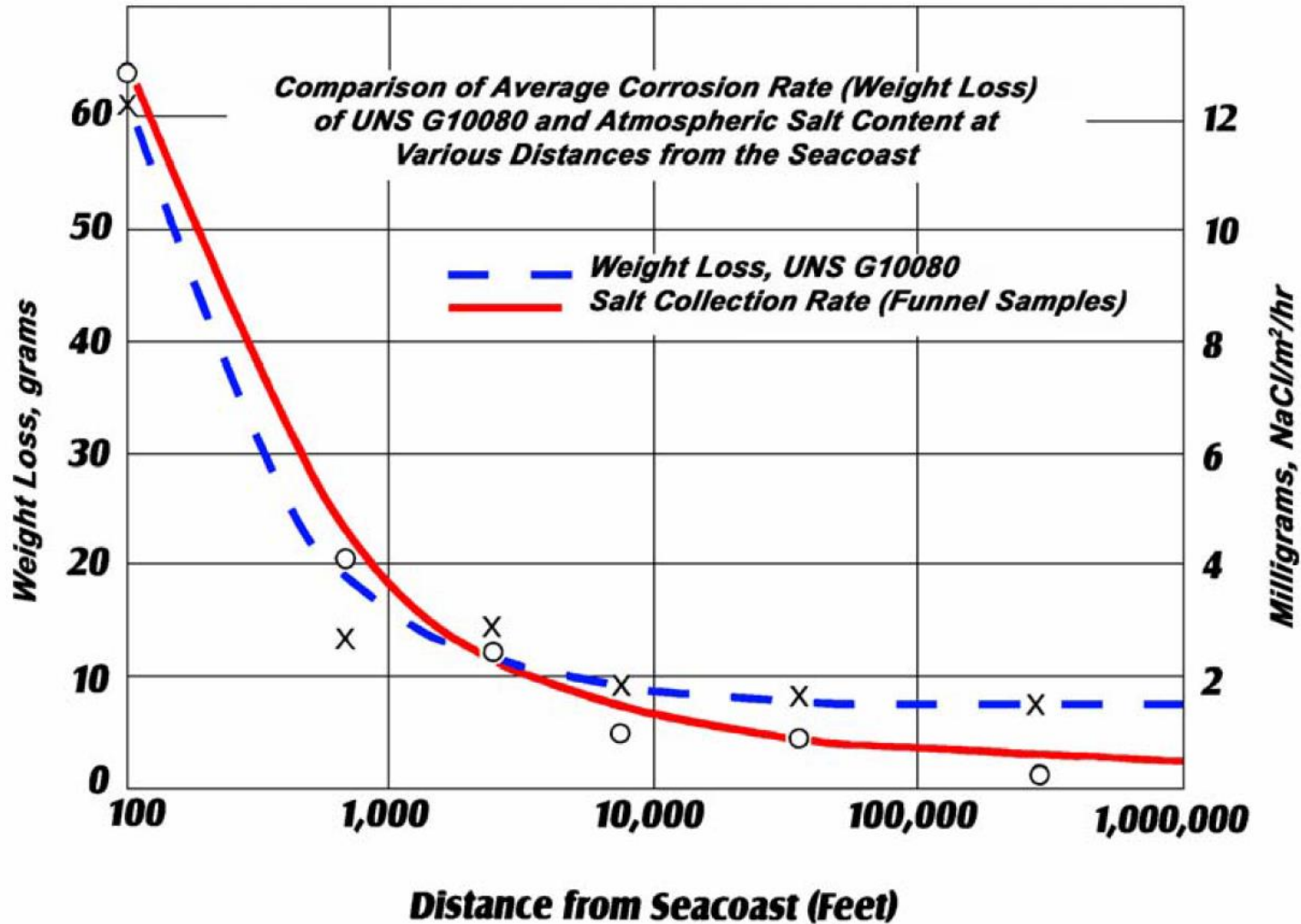
Cape Kennedy, April 1967



KSC Beachside Test Site,

Saturn V

Changes in Corrosion Rate with Distance from the Ocean*

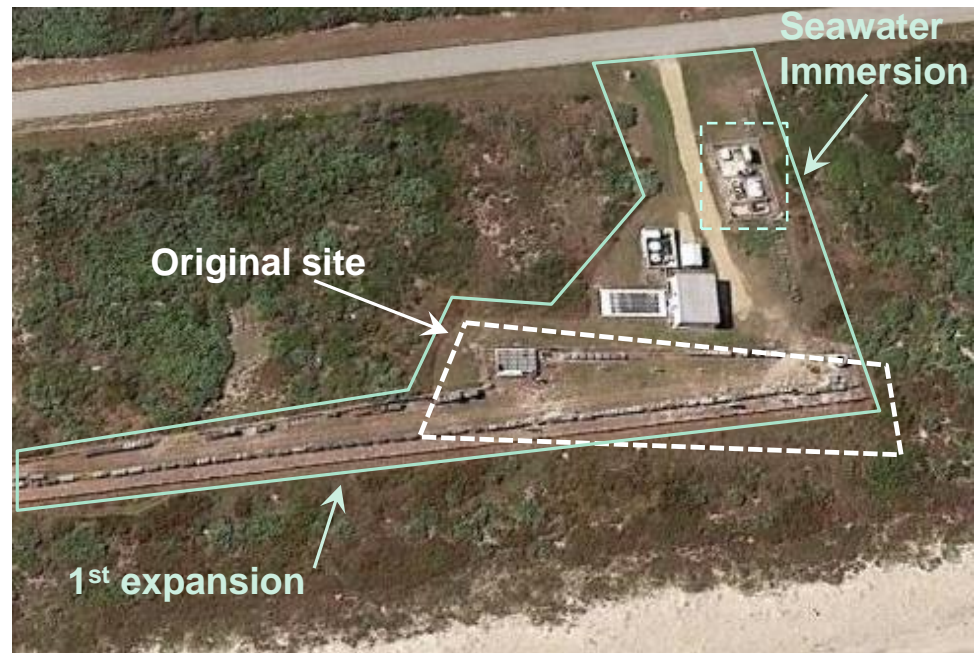


*J.D. Morrison, Report on the Relative Corrosivity of Atmospheres at Various Distances from the Seacoast, NASA-Kennedy Space Center, Report MTB 099-74, January 1980

1st Expansion



- **1990's:** Numerous studies at the site required an expansion to 600 feet parallel to the Atlantic Ocean
- Environmentally friendlier coatings, zinc-rich primers and inorganic topcoats, silicone ablative coatings
- Identified materials, coatings, and maintenance procedures for launch hardware and equipment exposed to the highly corrosive environment at the launch pad
- Results have helped NASA find new materials and processes that increase the safety and reliability of launch structures and ground support equipment



Upgrades

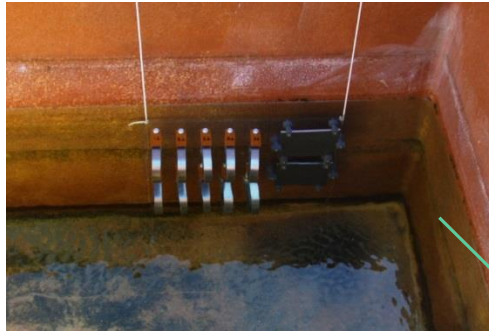


Upgrades:

- Weather station
- New permanent building with laboratory and machine shop
- Remote camera system
- Remote field monitoring

Seawater immersion:

- Simulates natural tidal conditions
- Water Quality (pH, dissolved oxygen, chlorides, temperature) Oxygen concentration monitored



Alternating Seawater Spray Test:

- Sprays seawater pumped from the ocean
- Frequency programmable



Concrete:

- Test rebar in concrete
- Electrically connected



2nd Expansion



- Site expansion as a result of current demand for additional corrosion testing from NASA, the Department of Defense and other external customers
- 900 total feet of coastal atmospheric exposure space parallel to the Atlantic Ocean
- 200 feet from the mean high tide line
- Accommodates specialty components



Atmospheric Corrosion Test Site



- Documented by ASM as one of the most corrosive naturally occurring environments.
- Actively maintained for 48 years.
- Historical database for evaluation of new materials.
- On-site laboratory for real time atmospheric and seawater immersion corrosion investigations.
- Remote access network connectivity for data acquisition and real time video by the Internet.
- Instrumented for complete weather information.



KSC Corrosive Environment



- **Natural Environment**

- ☐ Ocean salt spray
- ☐ Heat
- ☐ Humidity
- ☐ Sunlight

- **Atmospheric exposure can be time consuming, but the gold standard in lifetime prediction.**

- **Atmospheric exposure requires less labor as compared to most accelerated methods.**

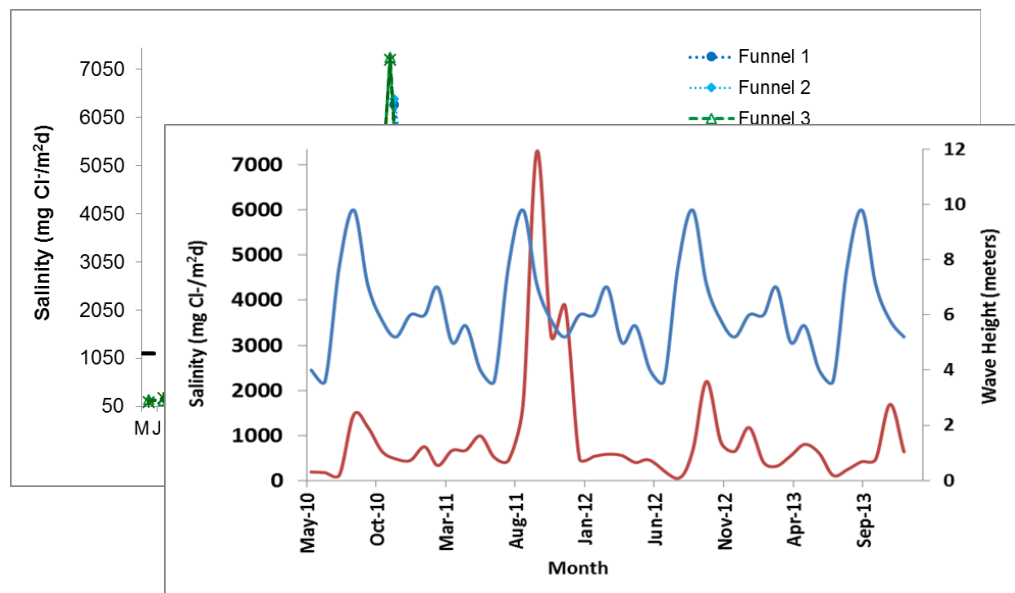
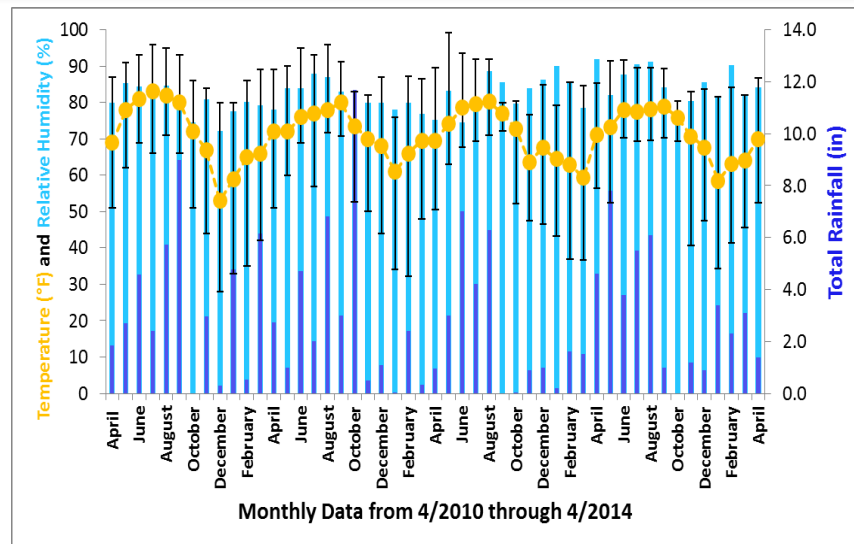
- **Thus far, no accelerated corrosion test method can satisfactorily correlate to atmospheric exposure.**



Monitoring of Natural Conditions



- **Temperature**
 - Ambient
 - Panel-specific
- **Relative humidity**
- **Precipitation**
- **UV exposure**
- **Wind (direction and speed)**
- **Chloride deposition**
- **Sulfur deposition**
 - NADP* FL99
 - 1-2 mg/m²-d (very low)
- **Wave height**
 - NOAA buoy #41009
 - Average over 10 years

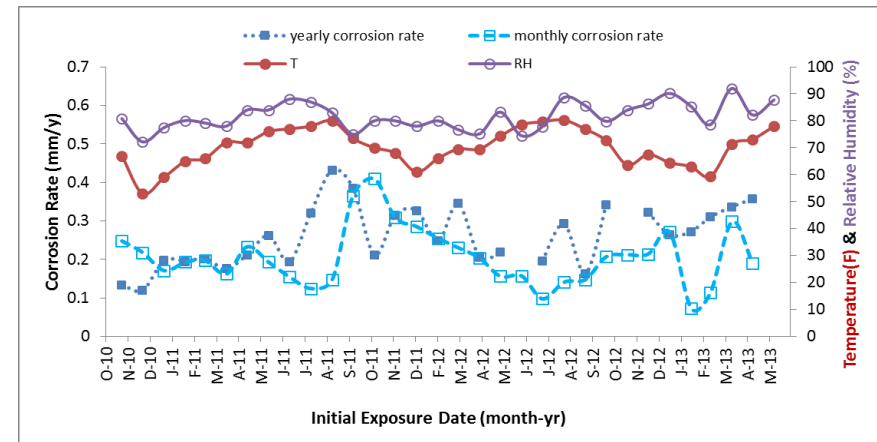
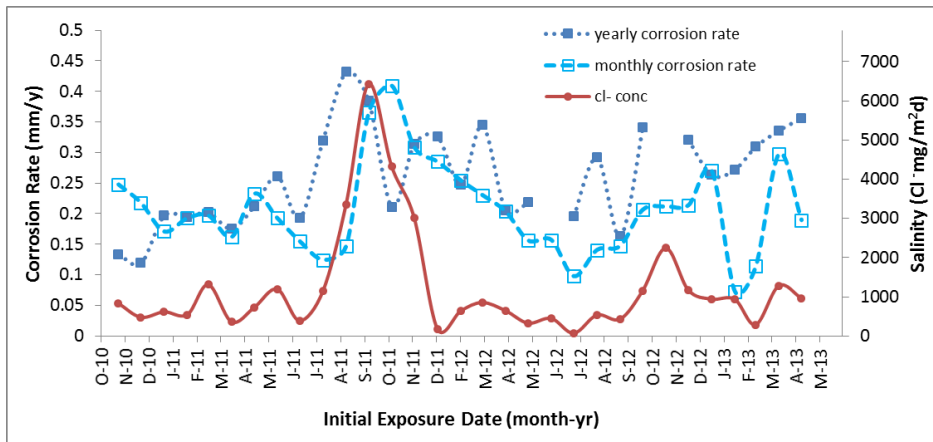
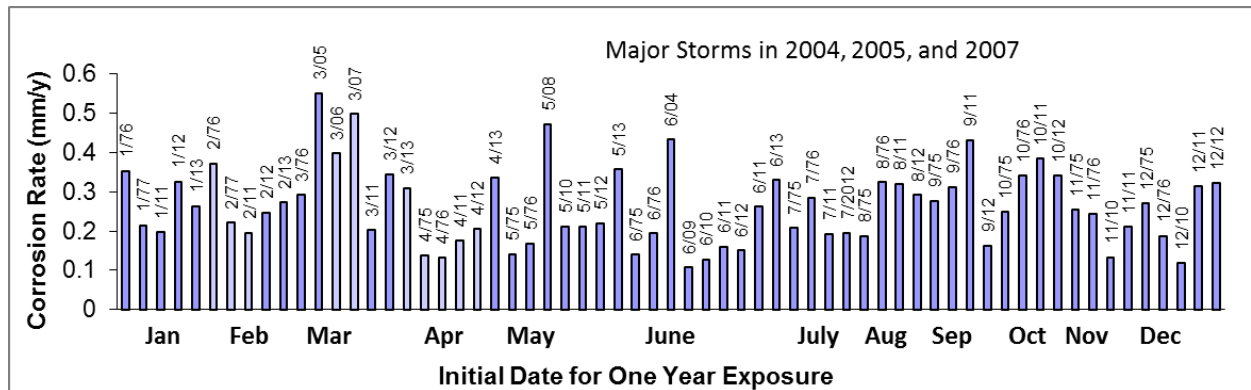


Monitoring Natural Conditions



Corrosion Rate

- Weight loss with carbon steel coupons
- Ranges from 0.127 – 0.51mm/y
- Rates vary seasonally and as a function of chloride/precipitation



NASA's Protective Coatings Standard

NASA-STD-5008B



- **Purpose**

- **To establish uniform engineering practices across NASA programs**
- **To provide a design standard for the development of specifications and requirements for**
 - **Safety**
 - **Materials**
 - **Equipment**
 - **Procedures**
 - **Quality assurance inspections**
 - **Provide and maintain a qualified products list**

Coatings Application Lab



- Equipped with state-of-the-art coating application equipment with conventional, airless, and plural component spray capabilities.
- Maintains an inventory of standard steel and aluminum test panels.
- Ensures that coatings are applied in a prescribed and consistent manner to SSPC, NACE International and military specifications.



Preparation of Test Panels



- **Standard AISI M1020 carbon steel test coupons**
Two types: composite and flat panel
- **Surface cleanliness & roughness of coupons**
Inspected, measured, and documented before application of primer

Composite Panel

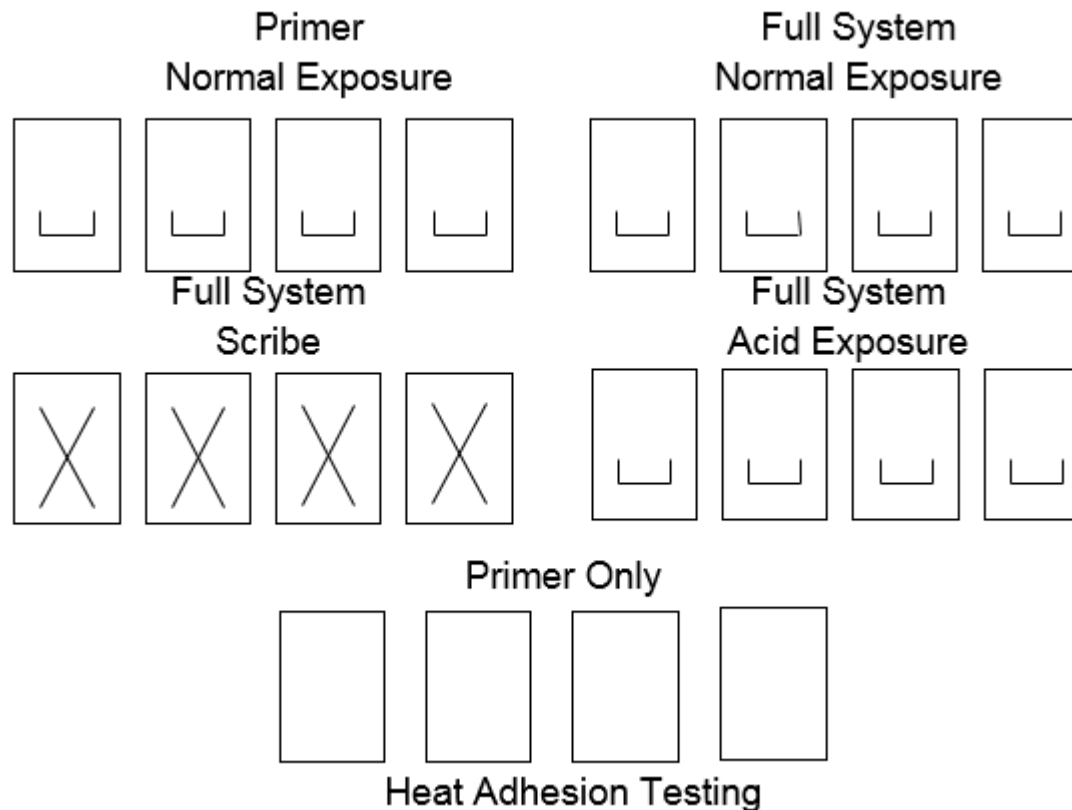


Flat Panel



Test Matrix

- 4 composite primer only (normal conditions)
- 4 composite top coated (normal conditions)
- 4 composite top coated (acid conditions)
- 4 flat top coated (scribe test – normal conditions)
- 4 flat primer only (to measure heat resistance/adhesion)



Laboratory Testing

■ Adhesion

- ☐ Preheat and Post Heat (400C – 24 hours) are recorded
- ☐ Post heat adhesion value must be greater than pre heat adhesion value, and meet the statistical requirements for repeatability

Atmospheric Exposure Testing

- ☐ Evaluations are performed after 18 months of exposure for initial qualification
- ☐ Final evaluations are performed after 60 months of exposure for final approval and placement on the approved products list
- ☐ The acidic slurry is placed on the appropriate panels every six weeks for the first 18 months of exposure.

■ Photographs

- ☐ Taken prior to exposure, and after 18 months and 60 months of exposure

■ Color/Gloss (Not a pass/fail criteria)

- ☐ Color and gloss are taken prior to, and after 18 months of atmospheric exposure

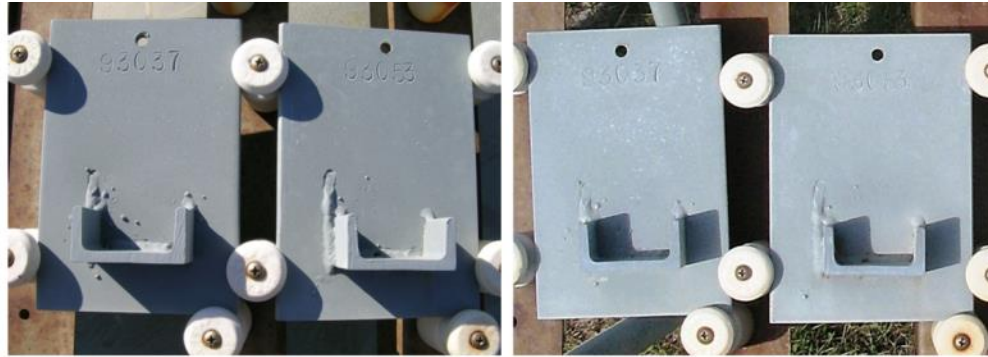
■ Blistering, corrosion under paint and corrosion from the scribe evaluations (Pass/fail criteria)

- ☐ Corrosion evaluations are performed after 18 months and 60 months of environmental exposure

Corrosion under Paint



- Corrosion under paint is a pass/fail Criteria
- Acid rinsed and non acid rinsed are evaluated by this method
- Corrosion Under Paint is determined via pictorial examples in ASTM D610, "Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surface"
- According to NASA-STD-5008B, a rating of 8 (>0.03% to 0.1% rusted for aliphatic polyurethane, water reducible, and polysiloxane topcoats) or 9 (>0.01% to 0.03% rusted for inorganic zinc).



18 month and 60 month exposure – Approved for Use

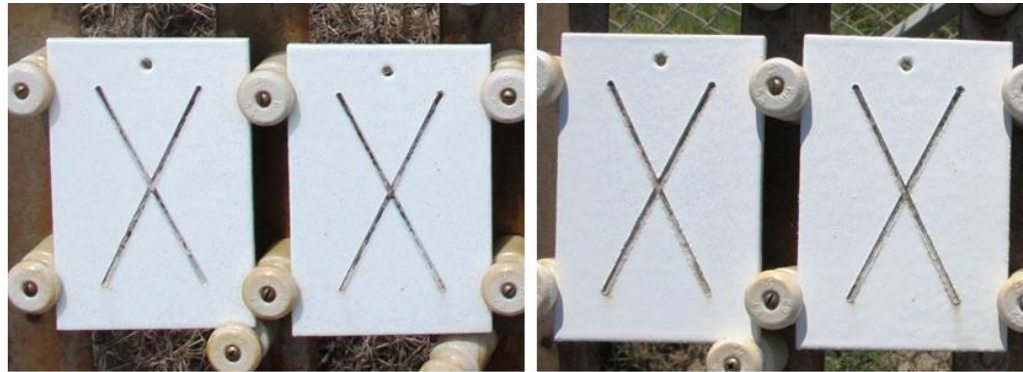


18 month and 60 month exposure – Not Approved for Use

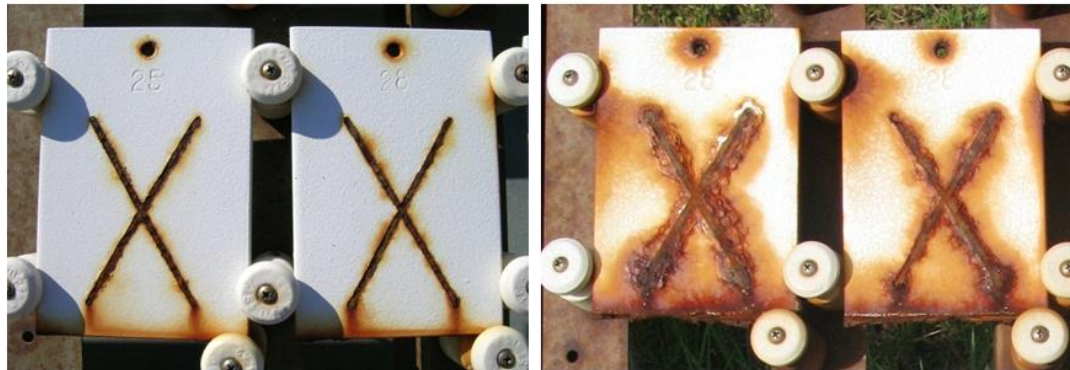
Corrosion from the Scribe



- Corrosion from the Scribe is a pass fail criteria
- These panels are not acid rinsed
- Corrosion from the Scribe is determined via measurements of creep from the scribed region according to ASTM D1654, "Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments"
- According to NASA-STD-5008B, a rating of 8 (mean creep > 0.5 mm to 1.0 mm for aliphatic polyurethane, water reducible, and polysiloxane topcoats) or 9 (mean creep > 0.0 mm to 0.05 mm for inorganic zinc).



18 month and 60 month exposure – Approved for use



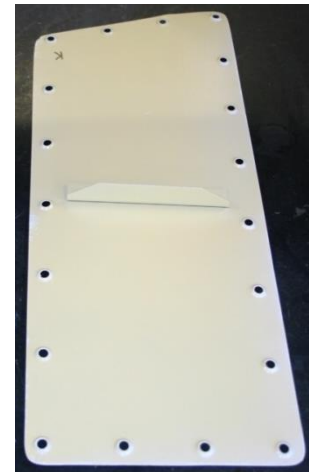
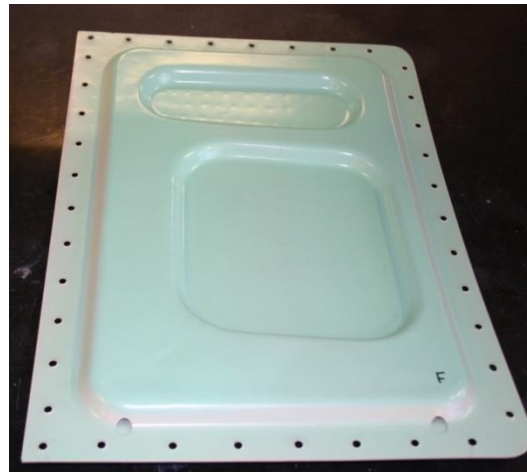
18 month and 60 month exposure – Not approved for use

Collaboration Highlights



Collaborative project between NAVAIR and NASA to evaluate hexavalent chromium-free coatings in a real world environment

NASA's P-3 Orion Aircraft – Stationed at WFF



Summary

- **What factors should be considered when selecting and constructing a test site?** It should represent a worst case scenario of the environment in which the assets of interest are located or operated.
- **What are the attributes of a “good” test site?** A secure location with local utilities and qualified, experienced on-site staff to provide services and maintenance. **Is more severe always better?** Having a worst case scenario is best; the levels of severity can be adjusted by modifying the exposure conditions.
- **What environmental parameters should be monitored?** Temperature, RH, UV, wind speed, wind direction, wave height, wave direction, dew point, time of wetness (TOW), atmospheric chloride deposition, corrosion rate, and rain. **How frequently?** Depends on parameter; most data can be hourly frequency, the salt profile is monthly, the corrosion rates are yearly. It is best to do corrosion rate panels at least every quarter providing overlap, to get seasonal effects.

Summary

- **What factors should be considered when designing test specimens?** The specimen should represent the asset in service conditions as close as practically possible.
- **Are current test standards sufficient?** They are adequate for the existing tests and provide a common language within the corrosion community.
- **How do diurnal, annual and other fluctuations in corrosivity influence tests?** They do affect the results and should be taken into account when analyzing the data.
- **How are test results interpreted?** Typically all evaluation parameters are agreed upon by the customer and evaluator before the test commences. This gets defined in the SOW or pre-test meetings. **Can they be quantified?** Yes. ASTM provides numerical ratings for most of their standards when it comes to corrosion evaluation; typically, a 10 – 0 scale, with 10 being the best and 0 the worst.

Acknowledgements

- Jerry Curran
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